Title of the research project: A reliability approach of the assessment of the failure of masonry and RC structures based on limit analysis and computational discrete modelling

Location:

INSA Rennes, France

Supervisors - Contacts:

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Background and skills expected from the successful applicant:

Advanced methods of structural analysis (Plasticity theory, Limit analysis and load bounds, Fracture analysis) – Structural design and analysis of structures (RC, masonry…) – Numerical methods in engineering (Finite element method…) – Applied mathematics (Variational methods in engineering) – Applied Statistics & Probabilistic Methods in Engineering – Matlab and Python Programming.

Keywords:

Limit analysis, Failure analysis, Probabilistic reliability, Load bounds and failure modes, Masonry and RC structures

Subject:

Investigating the failure of either concrete or masonry structures is a major ongoing issue in civil engineering. For this purpose, limit analysis is a valuable method that allows to estimate the bearing capacity and to determine associated failures mechanisms of loaded structures with a relatively reasonable computational cost since in such an approach there is no need to address their full non-linear response.

An underway Ph.D thesis (of Mohamad Moussa) supervised by Agnès Fliscounakis and Fekri Meftah at INSA Rennes has led to the elaboration of a 2D/3D computational model based on limit analysis. The model ([2], [1]) is developed within a discrete framework in which yield mechanisms occur at specific localised interfaces: joints between blocks in masonry, preexisting or expected fracture patterns in concrete structures. Moreover, it allows to consider several local failure modes: tensile cracking, shear failure with frictional contact, compressive crushing either with or without rocking. For these elementary failure mechanisms, mechanical (material) parameters (tensile and compressive strengths, cohesion, frictional angle, dilatancy angle…) are needed among other input data for the limit analysis.

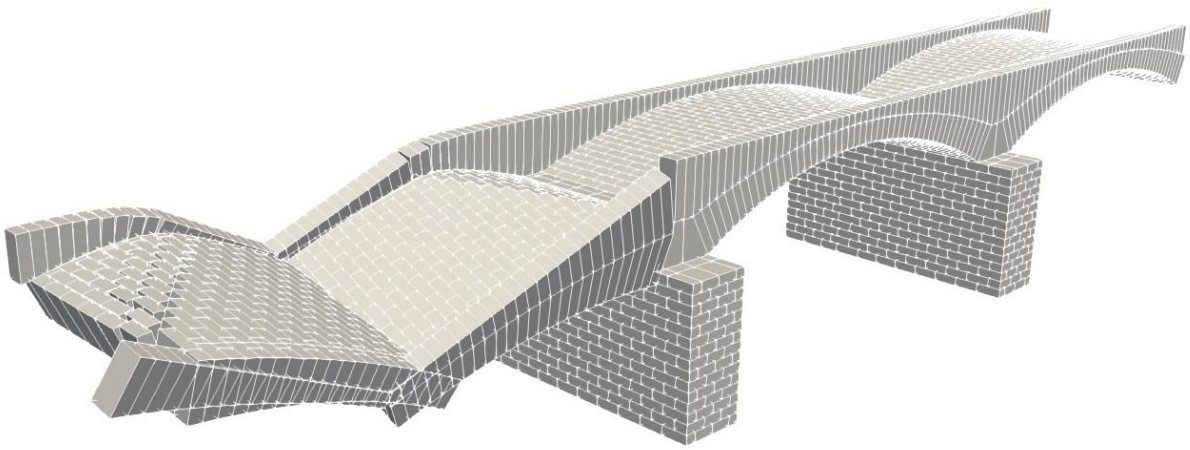

Fig 1: Failure mode of a masonry bridge (at Osserain, France) analysed with the developed DLACoM (Ph.D thesis - Mohamad MOUSSA)

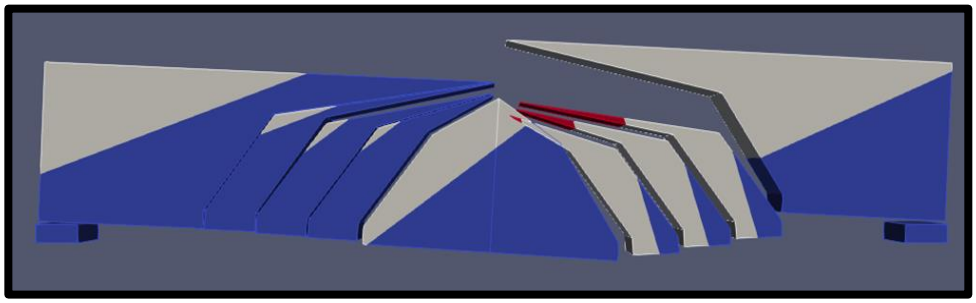

Fig 2: Crack patterns induced by a shear dominant failure of a RC beam analysed with the developed DLACoM (Master Internship - Aruntitya KONG)

However, one major issue is that the involved modelling parameters usually present random variability of their values. For each parameter, the dispersion may concern either its uncertain characteristic value to be considered in the analysis or its spatial inhomogeneity. Therefore, the impact of this uncertainty on the limit analysis prediction needs to be evaluated.

The aim of the proposed Ph.D thesis project is to investigate the sensitivity of failure load and associated kinematical mechanism to the variability of needed modelling parameters (geometry, material properties, boundary conditions, loadings, assumed failures patterns…). For this purpose, probabilistic methods will be adopted and coupled with an already developed discrete limit analysis computational model (DLACoM). Then, the approach will be dedicated to investigating the probabilistic safety of:

- Masonry structures [3] made of infinitely resisting blocs (Fig. 1),
- Renforced concrete (RC) beams failing in shear [4] by assuming a priori sets of explicit failure patterns (Fig. 2).

The research project task program is described hereafter:

- Literature review on (i) limit analysis and discrete modelling approaches applied to masonry and RC structures, and on (ii) statistical variability and probabilistic reliability methods [5,6…] in engineering for safety analysis of structures.
- Getting started with limit analysis of masonry/RC structures using DLACoM tool.
- Choice of a suitable probabilistic reliability method, numerical implementation within DLACoM (Python programming) and validation tests.
- Numerical simulations for sampling-based sensitivity study of failure/safety analysis of selected masonry/RC structures.
- Dissemination (journal and conference papers), writing of the Ph.D thesis manuscript and oral defence.

References

[1] M. Moussa, A. Fliscounakis, K. Ferradi, F. Meftah, Technical report on Osserain's Bridge, 2023.

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[4] J. Fisker, L. G. Hagsten, Mechanical model for the shear capacity of R/C beams without stirrups: A proposal based on limit analysis, Engineering Structures, 2016.

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[6] C. Wang, Z. Qiu, M. Xu, Y. Li, Novel reliability-based optimization method for thermal structure with hybrid random, interval and fuzzy parameters, Applied Mathematical Modelling 47 (2017) 573–586.